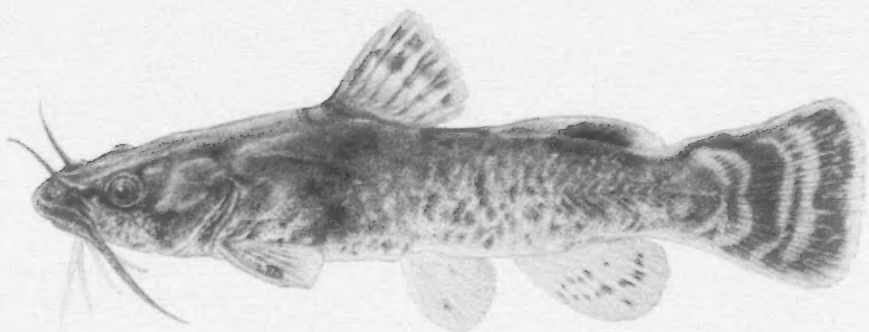
COSEWIC
Assessment and Status Report

on the

Northern Madtom
Noturus stigmosus

in Canada



ENDANGERED
2012

COSEWIC
Committee on the Status
of Endangered Wildlife
in Canada

COSEPAC
Comité sur la situation
des espèces en péril
au Canada

COSEWIC status reports are working documents used in assigning the status of wildlife species suspected of being at risk. This report may be cited as follows:

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Holm, E., and N.E. Mandrak. 1998. Update COSEWIC status report on the northern madtom *Noturus stigmosus in* COSEWIC assessment and update status report on the northern madtom *Noturus stigmosus* in Canada. Committee on the Status of Endangered Wildlife in Canada. Ottawa. 1-15 pp.

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COSEWIC
Assessment Summary

Assessment Summary – May 2012

Common name
Northern Madtom

Scientific name
Noturus stigmosus

Status
Endangered

Reason for designation
This species is one of the rarest freshwater fish in Ontario, being found at only four locations in river systems in southwestern Ontario. Substantial and ongoing threats in these rivers include siltation, turbidity, exotic species and toxic compounds, which have all been assessed as high levels of concern. Although there may be some localized improvement in habitat, overall there is an inferred continuing decline in habitat quality and substantial ongoing threats throughout its range.

Occurrence
Ontario

Status history
Species considered in April 1993 and placed in the Data Deficient category. Re-examined in April 1998 and designated Special Concern. Status re-examined and designated Endangered in November 2002 and May 2012.

COSEWIC
Executive Summary

Northern Madtom
Noturus stigmosus

Wildlife Species Description and Significance

The Northern Madtom is a small catfish that has a mottled colour pattern with irregular dark saddles on the back, with two large light spots in front of the dorsal fin. It has four pairs of barbels on the head, and venomous spines in the dorsal and pectoral fins. The Northern Madtom appears to be declining throughout much of its global range, and is a species that has always been rare in Canada.

Distribution

The Northern Madtom is found in the Ohio River and western Lake Erie and Lake St. Clair basins. In Canada, it is known only from the Detroit River, St. Clair River, Lake St. Clair, and two tributaries of Lake St. Clair, the Thames River and the Sydenham River. It is likely extirpated from the Sydenham River.

Habitat

Occupying a wide range of habitats, the Northern Madtom has been found in clear to turbid water of large creeks to big rivers with moderate to swift current. It occurs on bottoms of sand, gravel, and rocks occasionally with silt, detritus, and accumulated debris, and is sometimes associated with aquatic plants. It has also been found in lakes, usually close to a river source with a noticeable current.

Biology

The Northern Madtom is a warmwater species that has been collected in temperatures up to 28°C. Maximum known age of Northern Madtom is 3 years. The maximum known total length is about 130 mm. Most females are 2 years of age at the onset of maturity. The Northern Madtom spawns in July in Ontario, once water temperature reaches 23°C. A nest is constructed in a cavity or in an artificial substrate. The male guards the eggs and young for approximately one month. Clutch sizes can be as large as 160 eggs.

The Northern Madtom eats benthic invertebrates and small fishes. It appears to be tolerant of moderate turbidity.

Population Sizes and Trends

There have not been any studies on population sizes in Canada. Therefore, it is difficult to assess population sizes and trends. Approximately 235 Northern Madtom have been captured or observed at 66 sites in Canadian waters, with low capture rates predominant at most of them. It is unclear whether this low capture is a result of habitat degradation by human activities, habitat limitations at the northern edge of its range, difficulty in sampling the species effectively, or natural rarity. Targeted sampling of Northern Madtom has increased over the last few years, and it has been collected at several more sites since its last COSEWIC assessment.

The Northern Madtom likely has been extirpated from the Sydenham River.

Threats and Limiting Factors

Potential threats to the Northern Madtom include siltation and excessive turbidity, nutrient loadings, exotic species, toxic compounds, habitat loss and degradation, and climate change. Many of these are related to the agricultural and urban land uses that dominate the local landscape. Possible limiting factors are minimum temperature for spawning, spawning habitat requirements, low fecundity, and maximum age.

Protection, Status, and Ranks

The Northern Madtom was designated by COSEWIC as Endangered in 2002 and 2012. It is currently on Schedule 1 of the Canadian *Species at Risk Act*. The global NatureServe rank is G3 (vulnerable). The national rank is N1N2 meaning the species is considered critically imperiled/imperiled in Canada. The Ontario rank is S1 (critically imperiled). The species is designated endangered within this province and is therefore protected under the Ontario *Endangered Species Act, 2007*. Both the Canada General Status and Ontario General Status are "At Risk". In the Great Lakes states, the species has a sub-national rank of S1 (critically imperiled) in Michigan, Ohio, and Illinois, and S2 (imperiled) in Pennsylvania.

TECHNICAL SUMMARY

Noturus stigmosus
Northern Madtom Chat-fou du Nord
Range of occurrence in Canada: Ontario in Detroit River, St. Clair River, Thames River, Lake St. Clair, likely extirpated in Sydenham River

Demographic Information

Generation time (usually average age of parents in the population; indicate if another method of estimating generation time indicated in the IUCN guidelines(2008) is being used)	2-3 yrs
Is there an [observed, inferred, or projected] continuing decline in number of mature individuals?	Unknown
Estimated percent of continuing decline in total number of mature individuals within [5 years or 2 generations]	Unknown
[Observed, estimated, inferred, or suspected] percent [reduction or increase] in total number of mature individuals over the last [10 years, or 3 generations].	Unknown
[Projected or suspected] percent [reduction or increase] in total number of mature individuals over the next [10 years, or 3 generations].	Unknown
[Observed, estimated, inferred, or suspected] percent [reduction or increase] in total number of mature individuals over any [10 years, or 3 generations] period, over a time period including both the past and the future.	Unknown
Are the causes of the decline clearly reversible and understood and ceased?	Unknown
Are there extreme fluctuations in number of mature individuals?	Unknown

Extent and Occupancy Information

Estimated extent of occurrence	3330 km²
Index of area of occupancy (IAO) (2 km x 2 km grid) *Thames River: 100 km²* *St. Clair River: 40 km²* *Lake St. Clair & Detroit River: 40 km²* Index of area of occupancy (IAO) (1 km x 1 km grid) *Thames River: 57 km²* *St. Clair River: 28 km²* *Lake St. Clair & Detroit River: 22 km²*	180 km² 107 km²
Is the total population severely fragmented?	No
Number of locations* *St. Clair River, Lake St. Clair, Detroit River, Thames River, likely extirpated in Sydenham River*	4
Is there an [observed, inferred, or projected] continuing decline in extent of occurrence? *Despite loss of Sydenham River population, extent of occurrence has increased with new location in St. Clair River*	No
Is there an [observed, inferred, or projected] continuing decline in index of area of occupancy?	No
Is there an [observed, inferred, or projected] continuing decline in number of populations?	No

* See definition of location.

Is there an [observed, inferred, or projected] continuing decline in number of locations*? *Likely extirpation from Sydenham River, new location in St. Clair River.*	No
Is there an [observed, inferred, or projected] continuing decline in [area, extent and/or quality] of habitat?	Yes
Are there extreme fluctuations in number of populations?	No
Are there extreme fluctuations in number of locations*?	No
Are there extreme fluctuations in extent of occurrence?	No
Are there extreme fluctuations in index of area of occupancy?	No

* See Definitions and Abbreviations on COSEWIC website and IUCN 2010 for more information on this term.

Number of Mature Individuals (in each population)

Population	N Mature Individuals
Population sizes unknown due to low catch rates	Unknown
Total	Unknown

Quantitative Analysis

Probability of extinction in the wild is at least [20% within 20 years or 5 generations, or 10% within 100 years].	Unknown

Threats (actual or imminent, to populations or habitats)

Potential: Siltation and turbidity, nutrient loadings, exotic species, toxic compounds, habitat loss and degradation, and climate change

Rescue Effect (immigration from outside Canada)

Status of outside population(s)? USA: States adjacent to lakes Erie, Huron and Ontario (MI – S1; OH – S1; PA – S1)	
Is immigration known or possible? *From Michigan side of Detroit River*	Yes
Would immigrants be adapted to survive in Canada?	Yes
Is there sufficient habitat for immigrants in Canada?	Possibly
Is rescue from outside populations likely? *Habitat improvements on U.S. side of Detroit River might have led to increases in populations there.*	Yes

Current Status

COSEWIC: Endangered 2012

* See definition of location.

Status and Reasons for Designation

Status:	**Alpha-numeric code:**
Endangered	B1ab(iii)+2ab(iii)
Reasons for designation: This species is one of the rarest freshwater fish in Ontario, being found at only four locations in river systems in southwestern Ontario. Substantial and ongoing threats in these rivers include siltation, turbidity, exotic species and toxic compounds, which have all been assessed as high levels of concern. Although there may be some localized improvement in habitat, overall there is an inferred continuing decline in habitat quality and substantial ongoing threats throughout its range.	

Applicability of Criteria

Criterion A (Decline in Total Number of Mature Individuals): Not applicable. No information on the number of mature individuals available.
Criterion B (Small Distribution Range and Decline or Fluctuation): Meets Endangered B1ab(iii)+2ab(iii), as EO and IAO are both below thresholds for Endangered, the number of locations is less than 5, and a continuing decline in the quality of habitat for the species is inferred.
Criterion C (Small and Declining Number of Mature Individuals): Not applicable. No information on the number of mature individuals available.
Criterion D (Very Small or Restricted Total Population): Not applicable. No information on the number of mature individuals available.
Criterion E (Quantitative Analysis): Not applicable. No quantitative analysis was undertaken.

PREFACE

Since the last COSEWIC report for Northern Madtom in 2002, the extent of occurrence (EO) has increased from <1600 km^2 to 3330 km^2. It has been found at multiple sites on the Canadian side of one new waterbody (St. Clair River). The species also has been found at several additional sites in the Detroit and Thames rivers. These new occurrences likely reflect increased sampling effort targeted at Northern Madtom, and habitat improvements in the Detroit River. However, continued low capture rates in Canadian waters, including numerous sites where the species has not been detected, suggest that population size has remained low. Several potential threats to Northern Madtom have been identified, including siltation and excessive turbidity, nutrient loadings, exotic species (particularly Round Goby), toxic compounds, habitat loss and degradation, and climate change.

COSEWIC HISTORY

The Committee on the Status of Endangered Wildlife in Canada (COSEWIC) was created in 1977 as a result of a recommendation at the Federal-Provincial Wildlife Conference held in 1976. It arose from the need for a single, official, scientifically sound, national listing of wildlife species at risk. In 1978, COSEWIC designated its first species and produced its first list of Canadian species at risk. Species designated at meetings of the full committee are added to the list. On June 5, 2003, the *Species at Risk Act* (SARA) was proclaimed. SARA establishes COSEWIC as an advisory body ensuring that species will continue to be assessed under a rigorous and independent scientific process.

COSEWIC MANDATE

The Committee on the Status of Endangered Wildlife in Canada (COSEWIC) assesses the national status of wild species, subspecies, varieties, or other designatable units that are considered to be at risk in Canada. Designations are made on native species for the following taxonomic groups: mammals, birds, reptiles, amphibians, fishes, arthropods, molluscs, vascular plants, mosses, and lichens.

COSEWIC MEMBERSHIP

COSEWIC comprises members from each provincial and territorial government wildlife agency, four federal entities (Canadian Wildlife Service, Parks Canada Agency, Department of Fisheries and Oceans, and the Federal Biodiversity Information Partnership, chaired by the Canadian Museum of Nature), three non-government science members and the co-chairs of the species specialist subcommittees and the Aboriginal Traditional Knowledge subcommittee. The Committee meets to consider status reports on candidate species.

DEFINITIONS
(2012)

Wildlife Species	A species, subspecies, variety, or geographically or genetically distinct population of animal, plant or other organism, other than a bacterium or virus, that is wild by nature and is either native to Canada or has extended its range into Canada without human intervention and has been present in Canada for at least 50 years.
Extinct (X)	A wildlife species that no longer exists.
Extirpated (XT)	A wildlife species no longer existing in the wild in Canada, but occurring elsewhere.
Endangered (E)	A wildlife species facing imminent extirpation or extinction.
Threatened (T)	A wildlife species likely to become endangered if limiting factors are not reversed.
Special Concern (SC)*	A wildlife species that may become a threatened or an endangered species because of a combination of biological characteristics and identified threats.
Not at Risk (NAR)**	A wildlife species that has been evaluated and found to be not at risk of extinction given the current circumstances.
Data Deficient (DD)***	A category that applies when the available information is insufficient (a) to resolve a species' eligibility for assessment or (b) to permit an assessment of the species' risk of extinction.

* Formerly described as "Vulnerable" from 1990 to 1999, or "Rare" prior to 1990.

** Formerly described as "Not In Any Category", or "No Designation Required."

*** Formerly described as "Indeterminate" from 1994 to 1999 or "ISIBD" (insufficient scientific information on which to base a designation) prior to 1994. Definition of the (DD) category revised in 2006.

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The Canadian Wildlife Service, Environment Canada, provides full administrative and financial support to the COSEWIC Secretariat.

COSEWIC Status Report

on the

Northern Madtom

Noturus stigmosus

in Canada

2012

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WILDLIFE SPECIES DESCRIPTION AND SIGNIFICANCE

Name and Classification

Class: Actinopterygii (ray-finned fishes)

Order: Siluriformes (catfishes)

Family: Ictaluridae (bullhead catfishes)

Scientific Name: *Noturus stigmosus* Taylor, 1969

English Common Name: Northern Madtom

French Common Name: Chat-fou du Nord

The Northern Madtom, *Noturus stigmosus* Taylor 1969, (Figure 1) is one of 29 species in the genus *Noturus* of the bullhead catfish family Ictaluridae (Near and Harman 2006; Egge and Simons 2006). Based on molecular data and morphological variation, up to nine additional *Noturus* species await description (Burr and Stoeckel, 1999; Hardman 2004; Burr *et al.* 2005).

Figure 1. The Northern Madtom *Noturus stigmosus*. Illustration by Joe Tomelleri.

Taylor (1969) placed the Northern Madtom in the "*furiosus* group" (subgenus *Rabida*) along with three other species: *N. munitus* (Frecklebelly Madtom), *N. furiosus* (Carolina Madtom), and *N. placidus* (Neosho Madtom). The "*furiosus* group" is characterized by pectoral spines that are strong, long, and relatively well-serrated; a long dorsal spine and humeral process; a mid-caudal band that is dark and crescent-shaped; anterior dorsal fin rays with whitish tips; an adipose fin whose posterior margin is relatively free of the caudal fin; and an intermediate number of caudal fin rays (Taylor 1969).

Analysing morphological, allozymic, and chromosomal data, Grady and LeGrande (1992) corroborated a monophyletic relationship among members of an expanded "*furiosus*-group" consisting of seven species. These include the original four members of the group, and the addition of *N. eleutherus* (Mountain Madtom), *N. flavater* (Checkered Madtom), and *N. flavipinnis* (Yellowfin Madtom).

Using nucleotide sequence data, Hardman (2004) suggested a phylogeny more similar to that of Taylor (1969), including the sister relationship between *N. munitus* and *N. stigmosus*. No subspecies of *N. stigmosus* have been recognized, but Mayden *et al.* (1992) indicated that it might be polytypic, which may warrant its division into several species. More recently, the Northern Madtom underwent a taxonomic revision, in which Thomas and Burr (2004) determined that the allopatric populations occurring in the Coastal Plain streams of Mississippi and Tennessee were not Northern Madtom, but actually a new species, Piebald Madtom (*Noturus gladiator*). *N. gladiator* possesses the diagnostic characteristics of the "*furiosus* group" (Thomas and Burr 2004). Molecular data suggested that *N. gladiator* is most closely related to *N. stigmosus*, despite the former being more similar to *N. munitus* in body shape and pigmentation (Thomas and Burr 2004). Hardman (2004) found genetic divergence of *N. stigmosus* and *N. gladiator* to be very low (<1%), but because the two species are well differentiated morphologically and allopatrically distributed, it does not seem likely that gene flow has occurred recently. Thomas and Burr (2004) suggested occurrence of a recent speciation event, with morphological divergence rate exceeding that of mitochondrial DNA differentiation.

Morphological Description

Only five species of *Noturus* have been collected in Canadian waters (Coad 1995). One of these, the Margined Madtom (*Noturus insignis*), is likely not native to Canada (Mandrak and Crossman 1992) although some (McAllister and Coad 1974, Goodchild 1993) have suggested that it may be indigenous. The Brindled Madtom (*N. miurus*), and *N. stigmosus* differ from *N. insignis*, the Stonecat (*N. flavus*), and Tadpole Madtom (*N. gyrinus*), in having a mottled pattern with saddles on the back instead of a more uniform brown, grey or yellow colour. The two mottled Madtom also differ from the plain-coloured Madtom in having the posterior edge of the pectoral spine strongly serrated instead of weakly serrated (Holm and Mandrak 2001).

The Northern Madtom has an overall colour pattern that is mottled with three irregular dark saddles on the back located at the front of the dorsal fin, behind the dorsal fin and at the adipose fin. The characters above distinguish *N. stigmosus* from *N. miurus*, which has a dark blotch at the tip of the dorsal fin and a dark bar which extends to the extreme upper edge of the adipose fin. Unlike the Brindled Madtom, the dorsal and adipose fins of the Northern Madtom have pale distal margins. There are three or four irregular crescent-shaped bars on the caudal fin; the middle bar usually extending across the upper and lower caudal rays and touching the caudal peduncle. Two pale spots about three-quarters the diameter of the eye are usually present just anterior to the dorsal fin. Unlike the Brindled Madtom, which has a low adipose fin

continuous with the caudal fin, the Northern Madtom has a high rear edge to the adipose fin that is nearly free from the caudal fin. Finally, based on measurements done by Erling Holm at the Royal Ontario Museum, the distance from the notch between adipose and caudal fins to the origin of the dorsal fin is 1.6-1.7 times greater than the distance from the notch to the end of the caudal fin for Northern Madtom and 1.3-1.4 for Brindled Madtom.

Maximum total length for Northern Madtom is 132 mm. In spawning males, the head flattens, dark pigment diffuses, and conspicuous swellings develop behind the eyes, on the nape, and on the lips and cheeks. This description is a compilation of diagnostic characters based on observations of Royal Ontario Museum specimens and observations made by Trautman (1981), Page and Burr (1991), Etnier and Starnes (1993), and Holm *et al.* (2009).

Population Spatial Structure and Variability

At present, there are no known physical barriers to movement that could create any genetic structure isolation within the Canadian part of the Northern Madtom range. However, large areas of habitat that might be unsuitable between sites where the species has been found could possibly create isolation. There have been no genetic studies of differences within and between Canadian populations of Northern Madtom.

Designatable Units

There is no evidence supporting the identification of designatable units below the species level.

Special Significance

Noturus species exhibit cryptic behaviour and possess poison glands associated with the pectoral spines that are unique to the Canadian fish fauna (Scott and Crossman 1973). Madtom are also negatively phototactic and seek shelter during the day if light penetration reaches the substrate. As a result, madtoms are nocturnal in their foraging activity (McCulloch 1994), using barbels and other sensory organs along the body to locate prey (Keast 1985). One of the four *Noturus* species native to Canada, Brindled Madtom, was listed by COSEWIC as Special Concern (Campbell 1995), but was downgraded to Not at Risk in 2001. However, with the limited distributions of the Brindled Madtom, Margined Madtom, and Northern Madtom in Canada, the genetic diversity expressed by behaviour, ecology and morphology in the genus *Noturus* may be in jeopardy. Throughout North America, nearly one third (nine of 29) of the recognized species diversity in *Noturus* is undescribed (Burr and Stoeckel 1999; Hardman 2004; Burr *et al.* 2005). Additionally, 15 of the described species are classified as endangered, threatened, or vulnerable (Warren *et al.* 2000; Thomas and Burr 2004).

DISTRIBUTION

Global Range

The Northern Madtom is found in the Ohio River and western Lake Erie and Lake St. Clair basins (Figure 2). It occurs throughout most of the Ohio River basin in Kentucky, Indiana, Ohio and restricted areas of Illinois, Pennsylvania, and West Virginia. It is found in several western Lake Erie tributaries in Indiana, Michigan, and Ohio; and in the St. Clair River, Lake St. Clair, and the Detroit River, which form the border between Michigan and Ontario (Rohde 1980; Stauffer *et al.* 1982; Cincotta *et al.* 1986). It appears to have been extirpated from several areas within its United States range (NatureServe 2011).

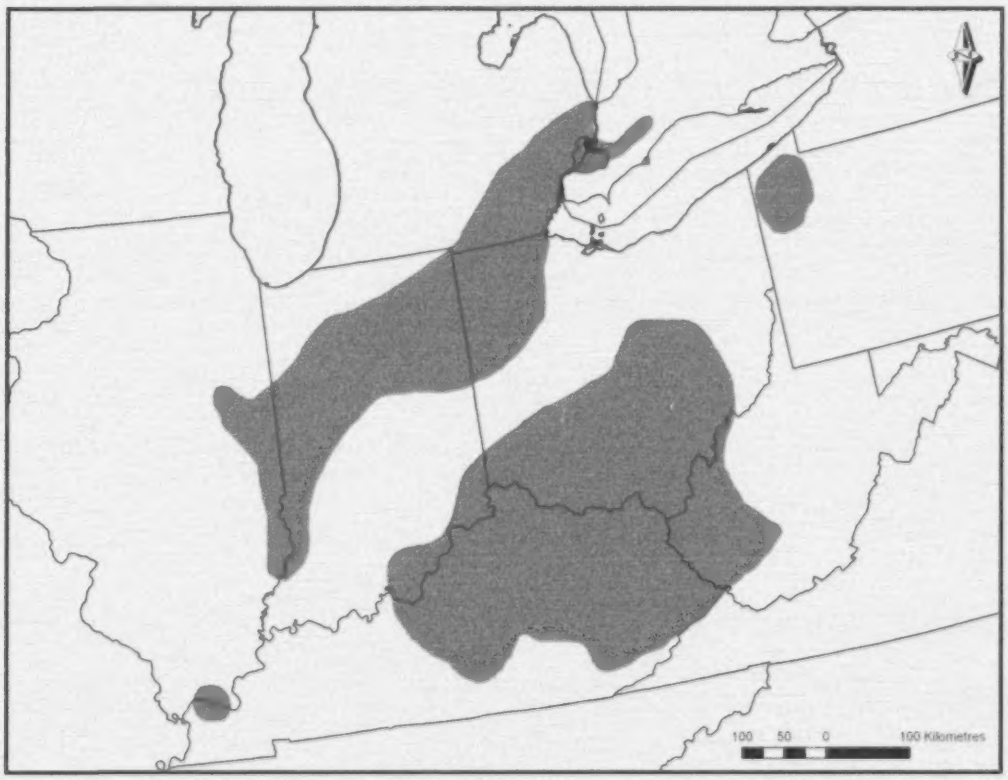

Figure 2. Global distribution of the Northern Madtom (modified from Page and Burr 1991).

Page and Burr (1991) stated that the Northern Madtom is relatively uncommon and has been disappearing from the margins of its range. Several historical sites in the Huron River in Michigan appear to no longer support Northern Madtom, with the only recent collection made at the type locality in 2005, where it was captured in lower numbers than in the past (MNFI 2010). In Pennsylvania, the species is restricted to one stream (French Creek), and appears to have been extirpated from one of the four counties in which it has been collected (Gutowski and Raesly 1993; Tzilkowski and Stauffer 2004). In Illinois, the species has not been collected since before 1979 (INHS 2011).

Range in Canada and Shared Waters

In Canada, the Northern Madtom is known only from the Detroit River, St. Clair River, Lake St. Clair, the Thames River and the Sydenham River (Figure 3). All of these waterbodies are found within the Great Lakes-Upper St. Lawrence biogeographic zone of the freshwater ecozone classification adopted by COSEWIC.

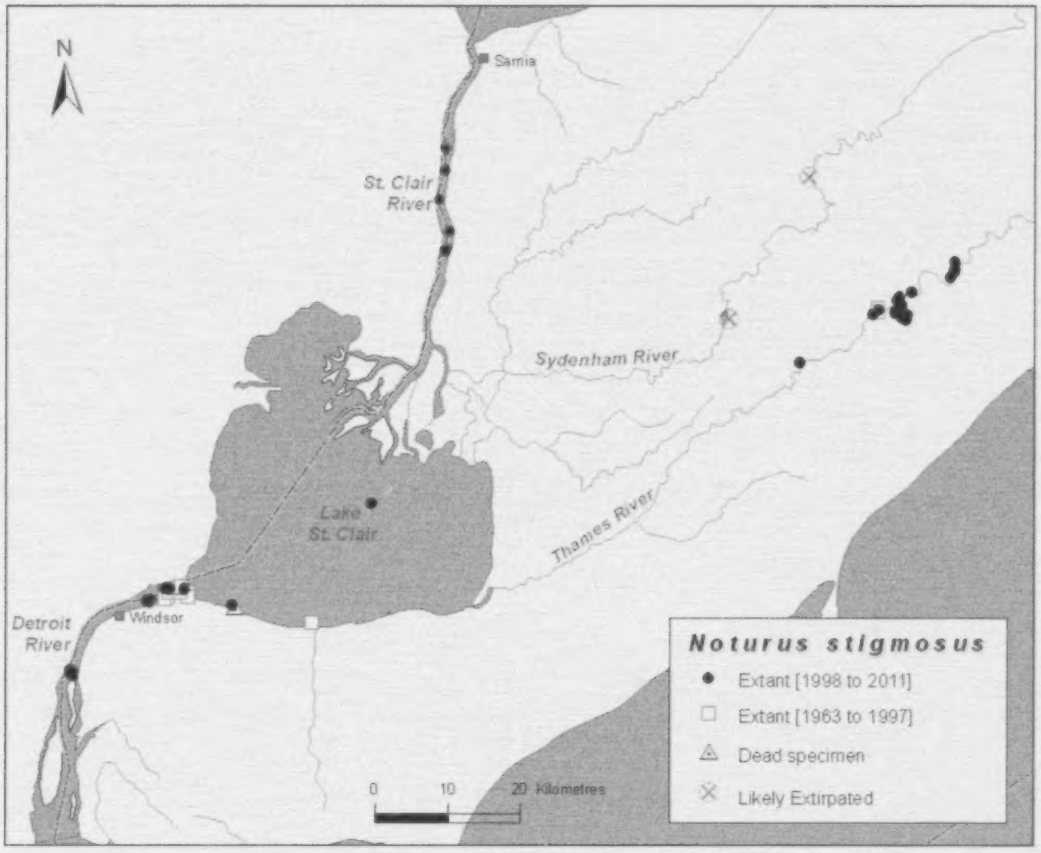

Figure 3. Canadian distribution of the Northern Madtom.

Lake St. Clair

Northern Madtom was first recorded in Canada in Lake St. Clair near the origin of the Detroit River where a single specimen was collected in 1963 (Trautman 1981). In 1996, three juveniles were seined at the mouth of Belle River approximately 19 kilometres east of the Detroit River (Holm and Mandrak 2001). In 1996, MacInnis (1998) observed Northern Madtom guarding egg clutches near the source of the Detroit River. In 1999, a specimen was captured off Walpole Island (ROM 72038). In 2007, one individual was found dead on the south shore of Lake St. Clair near the outlet of Pike Creek (ROM, unpubl. data).

Detroit River

On the Canadian side of the Detroit River, a single specimen was collected in 1994 near the first capture site in Lake St. Clair (ROM 68328). Northern Madtom has been collected in the area around Peche Island in 1996 (11 individuals), 2008 (69 individuals), 2009 (eight individuals), 2010 (two individuals), and 2011 (three individuals) (J. Barnucz, pers. comm. 2010; B. Manny, pers. comm. 2010). In 2009, seven Northern Madtom were found near Fighting Island. One Northern Madtom was found in this area in each of 2010 and 2011 (B. Manny, pers. comm. 2012). In September 2011, 15 Northern Madtom were captured at four nearshore sites south of Belle Isle in the Fleming Channel (J. Barnucz, pers. comm. 2011). Fleming Channel is used for shipping, and the lane is dredged to a minimum 8.5 metre depth (Manny *et al.* 1988).

On the United States side of the river, Northern Madtom was first collected in 1903 (University of Michigan Museum of Zoology; UMMZ 132009). In 1937, it was collected at the junction of Lake St. Clair and the Detroit River at the foot of Alter Road, Windmill Point. In 1978, it was reported on the impingement screen of the downtown Detroit coal-fired plant (Latta 2005). Between 2003 and 2008, a total of 205 Northern Madtom were captured near Belle Isle. In 2008, twenty Northern Madtom were captured near Conner Creek (B. Manny, pers. comm. 2012).

St. Clair River

Northern Madtom was first collected on the Canadian side of the St. Clair River by DFO in 2003, downstream of the Lambton Generating Station at the confluence of Clay Creek. In 2010, 6 individuals were collected between Stag Island and Clay Creek (J. Barnucz, pers. comm. 2010). On the American side of the river, 155 Northern Madtom were collected in 1994 adjacent to Algonac State Park, Algonac, Michigan (French and Jude 2001). Fourteen Northern Madtom were collected close to Algonac in 2010 (M. Thomas, pers. comm. 2010).

Sydenham River

One, perhaps two, specimens have been taken from the Sydenham River. A specimen collected near Florence, Ontario in 1975 (NMC 75-1623) was originally identified as a Brindled Madtom (*Noturus miurus*), but was reexamined by Erling Holm in 1999 and determined to be a Northern Madtom. A second individual was collected in 1929, before *Noturus stigmosus* was described by Taylor (1969), near Alvinston, Ontario (ROM 6675) and identified as *Schilbeodes miurus* (Brindled Madtom). Erling Holm re-examined the specimen in 2011. While its colour pattern has faded greatly, it does appear that there is a fairly wide pale edge on the adipose fin suggesting Northern Madtom. Also, the distance from the notch between the adipose and caudal fins and the end of the caudal fin (which has been shredded), into the distance between the notch and the origin of the dorsal fin is about 1.8, which also indicates Northern Madtom. Despite extensive sampling as recently as 2010 (Table 2, Figure 4), no Northern Madtom have been collected since 1975. Therefore, it is likely that the species has been extirpated from the Sydenham River.

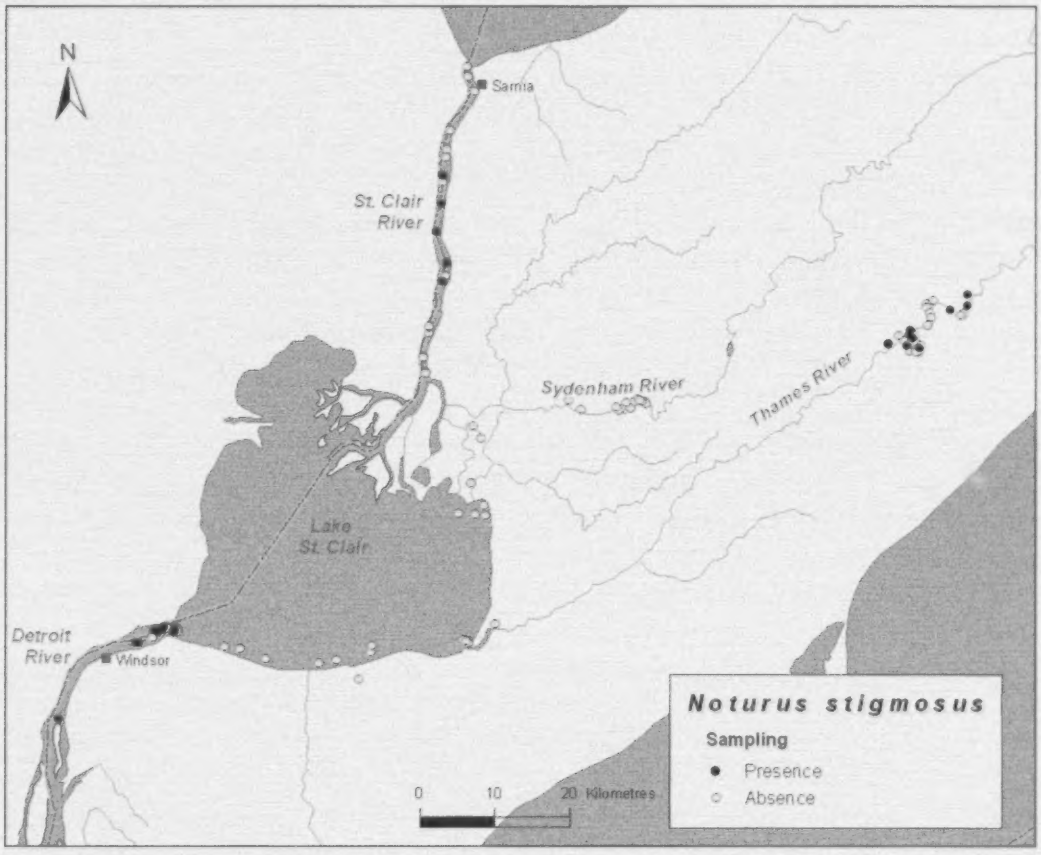

Figure 4. Locations of recent (2008-2011) targeted sampling for Northern Madtom in Canadian waters.

Thames River

In July 1991, an adult specimen was captured by the ROM in the Thames River near Wardsville. A juvenile specimen was captured in August 1997 at the same site. In 2003 and 2005, two Northern Madtom were captured below Wardsville at Littlejohn Road. This represents the downstream-most site for the species in the Thames River. Between 2003 and 2010, Northern Madtom were collected at 27 sites between Littlejohn Road and Tate Corners (Edwards and Mandrak 2006; M. Finch, pers. comm. 2010; A. Dextrase, pers. comm. 2010). The majority of the sites are located in, or near, the Big Bend Conservation Area. Northern Madtom has not been collected in recent sampling on the lower Thames River (Table 2, Figure 4).

The extent of occurrence (EO) of the Northern Madtom in Canada is estimated at 3330 km^2 based on minimum convex polygon within Canada's extent of jurisdiction. The index of area of occupancy (IAO), based on overlaid grid of cell size two km^2 (total IAO is the number of occupied squares that are intersected), is estimated to be 180 km^2 (107 km^2 using a 1 X 1 grid). The EO and IAO calculations exclude the Sydenham River.

Search Effort

Table 1 summarizes recent surveys conducted in areas where the Northern Madtom occurs. These include both targeted and non-targeted sampling.

Table 1. Summary of surveys (1996-2011) where Northern Madtom occurs (from Edwards *et al.* (2012), with additional data)

Waterbody	Survey Description (years of survey; effort)	Northern Madtom Captured (Y/N) (#)
Lake St. Clair	Ontario Ministry of Natural Resources nearshore fish community survey (2005; south shore) [a]	N
	Michigan Department of Natural Resources fish community survey (1996-2001; south shore)[b]	N
	DFO sampling (2003, 2004; St. Clair NWA)[d]	N
	ROM (2001-2002; Walpole Island)	N
	DFO/University of Guelph sampling (2003-2004; Mitchell's Bay) [d, e]	N
	Essex Erie (2007)[a]	N
	DFO sampling (2010)[b]	N
Detroit River	DFO/Windsor fish habitat association study (2003-2004) [a,d]	N
	DFO/University of Guelph coastal wetlands study (2004-2005)	N
	DFO Area of Concern sampling (2003-2004)	N
	DFO Northern Madtom Detroit River (2009) [b,e]	Y (8)
	USFWS-USGS sampling (2003-2011)[e]	Y (304)
	DFO Sampling (2010)[b]	Y (2)
	DFO/University of Windsor (2011)[b]	Y(15)
St. Clair River	ROM sampling (1996)	N
	DFO fish community sampling (2003, 2004)[d]	Y (1)
	DFO/University of Guelph fish community sampling (2007)[d]	N
	DFO sampling (2010)[b]	Y (6)
	USFWS sampling (2010)[e]	Y (14)

Waterbody	Survey Description (years of survey; effort)	Northern Madtom Captured (Y/N) (#)
Thames River	UTRCA fish SAR survey and gear comparison study 2003 and 2004, upper Thames River [a,c]	N
	DFO/UTRCA fish SAR survey and gear comparison study 2003 and 2004, lower Thames River and lower Thames tributaries [a,c]	Y (2)
	DFO/University of Windsor lower Thames River eastern sand darter (*Ammocrypta pellucida*) sampling (2006, 2007)[a]	Y (7)
	DFO/Trent University lower Thames eastern sand darter sampling (2006, 2007)[a]	Y(4)
	DFO Thames River trawling (2009)[b]	Y(11)
	DFO lower Thames sampling (2010)[b]	N
	DFO Mussel Trawl sampling (2010)[b]	Y (4)
Sydenham River	ROM non-targeted species at risk sampling (1997)[a]	N
	DFO/University of Guelph (2002) [a,c] (including night seining at Florence (historic site)	N
	DFO lower east Sydenham River (2010)[a,b]	N

Gear Type: a – seine; b – trawl; c – backpack electrofishing; d – boat electrofishing; e – additional gear (fyke nets, trap nets, trap lines, minnow traps)

Targeted Sampling in Canadian Waters

Figure 4 illustrates sites of targeted sampling from 2008-2011 for Northern Madtom in the Detroit, St. Clair, Thames, Sydenham, and Ruscom rivers, and Lake St. Clair conducted by Fisheries and Oceans Canada (DFO), the United States Geological Survey (USGS) and the United States Fish & Wildlife Service (USFWS). Table 2 summarizes all recent targeted sampling effort and catches. DFO has chosen a 2.5 m wide Missouri trawl net (MT) as the preferred method to target Northern Madtom. Typical specifications for an MT are an internal mesh of 19.05 mm bar mesh, and an external mesh of 4.76 mm heavy delta mesh. The cod end is 3.16 mm heavy delta mesh. The opening (footrope) is 2.4 m. Typical trawling transects were 100 to 200 metres in length (J. Barnucz, pers. comm. 2011).

Table 2. Search effort for recent targeted sampling for Northern Madtom (NMT) in Canadian waters by DFO[1], and USGS and USFWS[2].

Detroit River	Date	Method	Effort	# sites w. NMT	# NMT
	2008[2]	Baited Minnow Traps	120 trap-days	1	69
	July 2009[1]	Missouri Trawl	24 sites; 25 trawls; 12,500 m^2	3	4
		Trapline	7 sites; 32 traps baited with cheese, fished for 2 nights	2	4
	August 2010[1]	Missouri Trawl	8 sites; 8 trawls	2	2
	2011[2]	Baited Minnow Traps	2 sites; 123 trap-days	2	4
	September 2011[1]	Missouri Trawl	4 sites	4	15
St. Clair River	October 2010[1]	Missouri Trawl	30 sites; 98 trawls	5	6
		Bag Seine[c]	6 sites; 19 hauls	0	0
Lake St. Clair	August 2010[1]	Missouri Trawl	8 sites; 8 trawls	0	0
Ruscom River	August 2010[1]	Missouri Trawl	1 site; 2 trawls	0	0
Thames River	July 2008[1]	Unbaited Traps (4 trap types)	192 traps; ~4600 trap-hours	0	0
	October 2009[1]	Missouri Trawl	31 sites; 32 trawls; 7875 m^2	9	11
	October 2010[1]	Missouri Trawl	3 site; 9 trawls	0	0
Sydenham River	September 2010[1]	Missouri Trawl	15 sites; 16 trawls	0	0
	October 2010[1]	Missouri Trawl	1 site; 3 trawls	0	0

In 2008, DFO sampled the Thames River using traps at two sites near Big Bend, Ontario where recent Northern Madtom collections had occurred. Each site was approximately 350 metres by 40 metres. Forty-eight traps (4 trap types) were set within each site. Traps were unbaited, as it was thought that Northern Madtom would use the traps as hiding places so bait was not required. Sampling was conducted over two events (Site 1: July 17/18; Site 2: July 31/August 1). There were 192 separate sampling events (48 events per trap type) resulting in ~ 4600 hours of effort. Although no Northern Madtom were captured during this survey, two other Ictalurid species, Stonecat and Channel Catfish (*Ictalurus punctatus*) were collected (J. Barnucz, pers. comm. 2011).

In July 2009, DFO surveyed the Detroit River to determine if trapping was more effective than trawling in sites which have predicted greater abundance of Northern Madtom. Sites near Peche Island with current records of Northern Madtom were selected. Four trap lines consisting of 8 traps per line were used. Each trap line was 20 metres in length. Each trap was baited with cheese, following methods used by the USFWS (see below). The 32 traps were fished for two nights. Four Northern Madtom were captured (J. Barnucz, pers. comm. 2011).

Targeted sampling by the Royal Ontario Museum in 1996 in the St. Clair River failed to capture Northern Madtom. Sampling effort, which consisted of day and night trawls in 2-10 metres, and day and night seining in 0.1-1.3 metres (COSEWIC 2002) was similar to that undertaken on the American side in 1994 (French and Jude 2001; see subsection below).

Additional targeted sampling using minnow traps baited with Colby Jack cheese has been conducted by the United States Geological Survey (USGS) and the USFWS in the Detroit River from 2003 to 2011 to gain a better understanding of Northern Madtom distribution, abundance, reproduction and movements (B. Manny, pers. comm. 2010). Two sites were located on the Canadian side of the Detroit River. A site near Peche Island was sampled in 2008 and 2011. Sixty-nine Northern Madtom (which included 4 young-of-year) were captured over 120 trap-days in 2008, for a catch rate of 0.575 fish/trap-day. In 2011, three Northern Madtom were captured over 12 trap-days, for a catch rate of 0.25 fish/trap-day. The second site was located near Fighting Island, and has been sampled from 2007 to 2011. An artificial Lake Sturgeon spawning reef was constructed near this site in 2008. Northern Madtom were not collected in 2007 or 2008 (effort was 6 and 32 trap-days, respectively). In 2009, five Northern Madtom were captured over 72 trap-days, yielding a catch rate of 0.07 fish/trap-day. An additional two Northern Madtom were captured in this area in 2009 using drift nets. One Northern Madtom was captured in each of 2010 and 2011, yielding identical catch rates of 0.009 fish/trap-day (B. Manny, pers. comm. 2012).

Non-targeted/Multi-gear Sampling

In 2010, while sampling with a trawl for mussels in the Thames River, four Northern Madtom were collected at two sites in the Big Bend Conservation Area (N. Mandrak, unpubl. data).

In 2003 and 2004, the Thames River was sampled using multiple gear types. In 2003, 53 sites were sampled. Gear types were 8.5 m width bag seines (15 hauls at 10 sites); 10 m straight seines (30 hauls at 6 sites); 5.35 gillnet hours at 2 sites; large mesh fyke nets (20 hour set at 1 site); large mesh fyke net/minnow trap/Windermere trap (71.5 hours at 3 sites); large mesh fyke net/minnow trap (130 hours at 6 sites); small mesh fyke nets (124.5 hours at 7 sites); 2.3 hours of boat electrofishing at 18 sites; boat seining (10 hauls at 10 sites); and trawling (5 trawls at 2 sites). Despite this extensive effort, only one Northern Madtom was collected while boat electrofishing (Edwards and Mandrak 2006).

In 2004, a total of 41 sites were sampled on the Thames River mainstem, while 28 sites were sampled in 12 tributaries. A total of 521 seine hauls were undertaken from July to September. One Northern Madtom was collected. No Northern Madtom were collected while boat electrofishing. In the Thames River tributaries, 21 seine hauls at 8 sites and 6.38 hours of backpack electrofishing failed to collect Northern Madtom (Edwards and Mandrak 2006).

In 2006 and 2007, many sites targeted at capturing Eastern Sand Darter (*Ammocrypta pellucida*) in the lower Thames River were sampled. As part of a research project to develop predictive habitat models for the Eastern Sand Darter, systematic seining within randomly selected sample reaches (3 repeated hauls at each of 3 10x10 m sites on each wadeable bar within the randomly selected reach) was performed. A subsample of these sites (9 of 131) was resampled in 2007 and 2008. Four Northern Madtom were captured (A. Dextrase, pers. comm. 2010). In another study on Eastern Sand Darter in the Big Bend area of the lower Thames River, ten sandy depositional areas at five subsites were targeted. A 10 m bag seine was hauled for 10 m in three passes at each subsite. Seven Northern Madtom were captured (M. Fitch, pers. comm. 2010).

The furthest downstream that Northern Madtom has been captured in the Thames River is at Littejohn Road, southwest of Wardsville, Ontario. Two individuals were captured two years apart (2003 and 2005) while benthic kick sampling was being undertaken to collect benthic macroinvertebrates (A. Dextrase, pers. comm. 2010). It is interesting to note that Stonecat has been collected with this sampling method in surveys targeting benthic macroinvertebrates in the Rouge River in southeast Michigan (B. McCulloch, unpubl.data 2008).

Targeted Sampling on American Side of Shared Waters

As mentioned previously, USGS and USFWS have been conducting targeted sampling for Northern Madtom in the Detroit River. The construction of artificial spawning reefs designed for Lake Sturgeon near Belle Isle and Fighting Island created an additional opportunity to document use of the reefs by other species, such as Northern Madtom (B. Manny, pers. comm. 2010). Pre-reef construction sampling near Belle Isle in 2003 yielded 9 Northern Madtom for a catch rate of 0.05 fish/trap day. Post-reef construction sampling conducted in 2005 and 2006 yielded 19 and 43 Northern Madtom, respectively. This translates into catch rates of 0.03 fish/trap day in 2005 and 0.30 fish/trap day in 2006 (Manny 2006). In 2008, a total of 137 Northern Madtom were collected, for a catch rate of 0.21 fish/trap day (B. Manny, pers. comm. 2010).

One other site sampled in 2008 near Connor Creek yielded 20 Northern Madtom for a catch rate of 0.08 fish/trap day. A portion of the Detroit River shoreline was rehabilitated at this location in 2003 (GLIN 2012). Three other sites sampled in 2008, and 9 other sites sampled in 2011 failed to produce Northern Madtom (B. Manny, pers. comm. 2012).

Recent sampling conducted in 2010 in the St. Clair River near Algonac, Michigan yielded 14 Northern Madtom for an approximate catch rate of 0.085 fish/trap day. Again, minnow traps attached to setlines and baited with Colby Jack cheese were used (M. Thomas, pers. comm. 2011).

In 1994, French and Jude (2001) sampled the St. Clair River adjacent to Algonac State Park on seven dates between May and December. Kick sampling and seine nets

were used to collect benthic fishes in the nearshore areas, while a semi-balloon otter trawl with a 4.9-m headrope and 5.8-m wide footrope was used to capture benthic fishes at 3 m, 5 m and 7 m depths (French and Jude 2001). Sampling was performed during both the day and at night. Each trawl lasted approximately ten minutes. No Northern Madtom were collected in the nearshore areas. The trawls produced totals of 90, 30 and 25 Northern Madtom at the 3m, 5m, and 7 m depths, respectively. All but seven individuals (all on May 9 at the 5 m depth) were collected at night (French and Jude 2001).

HABITAT

Habitat Requirements

The Northern Madtom occupies a wide range of habitats. These include clear to turbid water of large creeks to big rivers and lakes with moderate to swift current. It occurs on bottoms of sand, gravel and rocks occasionally with silt, detritus, and accumulated debris, and is sometimes associated with macrophytes (Taylor 1969; Smith 1979; Trautman 1981; Cooper 1983; Burr and Warren 1986; Robison and Buchanan 1988; Carman 2001). The lentic environment is usually close to a lotic source, and has a noticeable current (J. Barnucz, pers. comm. 2010).

On the Canadian side of the Detroit River, it has been captured at depths of 1-7 m on smooth, firm bottoms often covered by macrophytes such as *Chara*. Recent targeted sampling captured Northern Madtom in slow run habitat in open water with substrates of mostly sand and clay (N. Mandrak, unpubl. data). On the American side near Belle Isle, it has been collected in depths of 6-8m with limestone, sand, rock and rubble substrates, as well as hard pan clay (B. Manny, pers. comm. 2010).

The Northern Madtom has been found in Lake St. Clair near the outlet of the Detroit River and around Belle River on sandy substrate devoid of cover. It has also been collected in areas with modest accumulations of silt and detritus and heavy growths of aquatic macrophytes (Holm and Mandrak 1998; MacInnis 1998; Edwards *et al.* 2012).

On the American side of the St. Clair River, Northern Madtom were collected in 1994 at depths of 3 to 7 metres, from the crest of the shipping channel to along the slope of the channel (French and Jude 2001). In 2010, Northern Madtom collected on the Canadian side were also found in depths of 3-7m in moderate to fast current (0.3-0.6 m/s) (J. Barnucz, pers. comm. 2010).

In the Thames River, the two specimens captured in 2003 and 2004 were in highly turbid water (Secchi <0.2m) on a bottom consisting of sand, gravel and rubble from areas where the substrate was free of silt and clay. Current was moderate, maximum depth of capture was 1.2m, water temperature was 23-26°C, conductivity was 666µS/cm, and pH was 7.9 (Edwards and Mandrak 2006). The one adult captured in

2006 was found in an area where water depth was 60-70 cm, flow (bottom) was 0.1-0.2 m/s, mean substrate size was 60-80 mm, dissolved oxygen was 8-8.5 mg/l and water clarity was 6-8 cm (Dextrase, unpubl. data). The juveniles/young-of-year collected in 2006 and 2007 were found in areas where water temperature was 19.5-28°C, pH was 8.03-8.47, dissolved oxygen was 6.0-10.05, depths were 0.06 to 0.90 m, and near bottom velocity was 0-0.55 m/s. Channel widths were 21-55 m. Substrate was mostly sand with gravel and silt (M. Finch, unpubl. data; A. Dextrase, unpubl. data). During recent targeted sampling, Northern Madtom were found in moderate flows in mostly run habitat at an average depth of 1.9 m (1.6 m to 2.4 m range). Average Secchi depth was 0.29 m. Distance from shore when captured ranged from seven to 23 m. Predominant substrate types were gravel (4 sites), sand (2 sites) and cobble (1 site) (N. Mandrak, unpubl. data.).

In the Licking River, Kentucky, Scheibly (2003) found that moderate current averaging 0.50m/s was preferred.

Habitat Trends

Agricultural land use and urbanization are prevalent throughout the Northern Madtom's Canadian range. Although not documented specifically for Northern Madtom, these landscape types typically affect habitat in a negative manner (Fitzpatrick *et al.* 2005; Diana *et al.* 2006).

Potential physical habitat loss specific to Northern Madtom in Canada includes dredging the shipping corridor from the St. Clair River to Lake Erie, as well as lake and river shoreline modifications (e.g., shoreline stabilization projects, docks, marinas) along the Detroit River and Lake St. Clair (Dextrase and Mandrak 2006). Edwards *et al.* (2012) classify the severity of physical habitat loss as "high" in the Detroit River/Lake St. Clair and St. Clair River.

The populations of Northern Madtom in the Detroit and St. Clair rivers are in two of the 43 "Areas of Concern" in the Great Lakes region. The rivers have been identified by the United States and Canada as having 14 beneficial uses which have become impaired (GLIN 2012). These include degraded fish and wildlife populations and loss of fish and wildlife habitats (Hartig *et al.* 1996). Several toxic compounds are present in the sediments of the Detroit and St. Clair rivers, including PCBs, PAHs, metals, oils and greases (U.S. Environmental Protection Agency 2009).

A Remedial Action Plan was initiated and several projects have been undertaken to improve water quality and increase the amount of fish habitat in the Detroit River. For example, in 2004-05 contaminated sediments were dredged from Black Lagoon. This was the first *Great Lakes Legacy Act* dredging site. In 2003, a portion of the Detroit River was rehabilitated as part of a combined sewer outflow disinfection basin project undertaken by the Detroit Water and Sewerage Department. This work took place at Conner Creek, on the U.S. side of the Detroit River, near Belle and Peche islands. Work included dredging of the creek, as well as the shoreline rehabilitation (GLIN 2012). In

2008, 20 Northern Madtom were captured in the Detroit River near the mouth of Conner Creek (B. Manny, pers. comm. 2012).

With the construction of Lake Sturgeon spawning reefs near two islands in the Detroit River featuring the addition of limestone, fieldstone and cinder substrates, and the aforementioned shoreline rehabilitation near Conner Creek, it appears that habitat for Northern Madtom has been improved. The abundance of Northern Madtom increased over a two month sampling period from May to June 2006 (Manny 2006). Over 200 Northern Madtom were captured in the Detroit River in 2008 (B. Manny, pers. comm. 2010). Given that spawning for the species in Lake St. Clair occurs between mid-July through mid-August (MacInnis 1998), the increased abundance at the Lake Sturgeon spawning beds may have been due to male madtoms preparing nest sites (Manny 2006). In fact, adult Northern Madtom were observed on artificial spawning mats (Manny 2006). While all of the "new" substrates were occupied by Northern Madtom, no particular preferences over the course of the study were observed between the new substrates and those existing before construction (B. Manny, pers. comm. 2010). A possible scenario is that Northern Madtom were keying in on the heterogeneity of the artificial reef substrates to spawn, and then moving to different habitats for other activities.

A Remedial Action Plan also was initiated for the St. Clair River in 2005. Wetlands were developed near Corruna, Ontario to treat wastewater prior to discharging into the river. Work undertaken here is a part of the long-term site restoration plan. In 2001, Sarnia, Ontario completed upgrades in sewage treatment. Retrofitting of storm water management infrastructure is ongoing. On the American side, five major wastewater treatment plants in Michigan have completed upgrades to their treatment facilities. These upgrades will improve sludge storage options and discharge mixing, and separate sewer systems to eliminate untreated combined sewage (GLIN 2012).

Griffiths *et al.* (1991) stated that the Canadian side of the St. Clair River was more polluted than the American side. The absence of Northern Madtom from the Canadian side in 1996 lies in stark contrast to the 155 Northern Madtom collected on the American side in 1994 (French and June 2001). The presence of Northern Madtom at five sites on the Canadian side in 2010 perhaps indicates that water quality is improving.

Land use in the Thames River watershed is dominated by agriculture (about 78% in the upper Thames River and 88% in the lower) (Taylor *et al.* 2004). Pollutants in the Thames River may include chloride (e.g., from road salt, wastewater treatment and water softeners) and metals, as well as pesticides from both agricultural and urban areas (TRERT 2004). Other potential factors that might contribute to habitat loss include siltation and turbidity, nutrient loadings, and toxic compounds (Edwards *et al.* 2012) (see Threats Section for further detail).

In the Sydenham River, similar potential factors to those affecting habitat in the Thames River are present. High turbidity is presumed to be a result of suspended solid loading from farm land. Loadings of clays from tile drains are also considered to be significant. On most monitoring occasions, phosphorus concentrations have exceeded the provincial water quality objectives. Sewage treatment plants are an additional nutrient source. Chloride concentrations have been increasing in the North and East Sydenham River (JWEL 2001).

BIOLOGY

General

The Northern Madtom is a warmwater species that has been collected when temperatures have ranged from 11 to 28°C. Maximum known age of Northern Madtom is 3 years (Scheibly 2003). The maximum known total length is 132 mm (Edwards *et al.* 2012). In Kentucky, growth appears to be quite fast, with young-of-year reaching 35-40 mm standard length (SL) at three months and 45-50 mm SL by year one (Scheibly 2003). Growth rates in Canada appear to be slower, as MacInnis (1998) captured a young-of-year in late October 1996 that was 30 mm TL, and a 19 mm specimen was collected in the St. Clair River in early November 2003 (J. Barnucz, pers. comm. 2010). These apparent slower growth rates may be due to shorter growing season.

Reproduction

Scheibly *et al.* (2008) stated that both sexes of Northern Madtom come into reproductive condition in early summer and exhibit secondary sexual dimorphism at this time. Breeding seems to occur in July in most parts of its range (Taylor 1969; MacInnis 1998; Scheibly *et al.* 2008). Age at maturity is reached at 2 years (Taylor 1969) and 60 mm SL, although Scheibly *et al.* (2008) provided evidence for early maturation at 13 months for females.

Northern Madtom is a cavity nester, with nests constructed in depressions under large rocks, logs and inside crayfish burrows, and in anthropogenic debris such as bottles, cans and boxes (Taylor 1969; Cochran 1996). MacInnis (1998) observed and videotaped nesting of 21 adult Northern Madtom in Lake St. Clair during the summer of 1996 while conducting research on the Round Goby, *Neogobius melanostomus.* The Madtom did not use the artificial goby nests themselves, but excavated 5 cm deep cavities in sand substrates beneath the nests (MacInnis 1998). Gravid females and recently spawned eggs were observed on 24 July 1996 near Peche Island. The nests were set in gentle current on a sandy bottom surrounded by a thick bed of aquatic macrophytes (primarily *Chara*). Eggs were approximately 3 mm in diameter and clutch size was conservatively estimated to range from 32 to 160. The male guarded both the eggs and newly hatched fry and did not abandon the nest when disturbed. Larvae and juveniles about 9 mm total length were observed being guarded by males on 13 August. The temperature during this period was 23°C. A male Brindled Madtom was also

observed nesting during this period but would abandon the nest when disturbed. Gravid females were observed as late as mid-August, suggesting a reproduction season of at least one month (MacInnis 1998).

In Kentucky, Scheibly *et al.* (2008) observed Northern Madtom nesting in cavities 4-7 cm deep under slab rocks in a raceway upstream of a large riffle in mid-July. Water temperatures were 23-25°C and velocities were 0.36-0.69 m/s. Water depth at the nests ranged from 0.26 to 0.46 m. Clutch sizes were estimated to be between 70-110 eggs. Eggs incubated in the laboratory hatched 13 days after fertilization. Hatchlings were 7.1-9.3 mm TL, and yolk sacs had been absorbed within 10 days. About one month after hatching, 20 mm SL young had moved downstream from the raceway into the large riffle (Scheibly *et al.* 2008). MacInnis (1998) witnessed both larval and juvenile Northern Madtom in nests being guarded by adult males approximately one month after occupation of nests was first observed. In Michigan spawning takes place in mid- to late July. Clutch sizes in Michigan range from 61 to 141 eggs (Taylor 1969). In Pennsylvania, mature female Northern Madtom collected in mid-June had an average oocyte diameter of 1.83 mm, and average clutch size of 98 eggs. Relative fecundity (oocytes/g of body weight) was 20.2 (Tzilkowski and Stauffer 2004).

Diet

Much of the diet of the Northern Madtom consists of aquatic macroinvertebrates, including mayflies, caddisflies, and chironomids. Small fishes and crustaceans are also consumed. While Northern Madtom are generally opportunistic feeders, in Pennsylvania, Tzilkowski and Stauffer (2004) found that they preferentially selected blackflies and stoneflies, while avoiding midge and riffle beetles. All other prey items were consumed in the same proportion to their relative abundance in the stream. This occurred in riffles co-inhabited by Stonecats. In the St. Clair River, French and Jude (2001) found that at 3 m depth, Northern Madtom fed heavily on mayfly nymphs (*Hexagenia*; Ephemeridae and *Baetisca*; Baetiscidae). At 5 and 7 metre depths, large Northern Madtom added Brachycentrid caddisflies, amphipod crustaceans and fish to their diet. Fish species that were consumed by Northern Madtom included Round Goby, an unidentified minnow, and other Northern Madtom (French and Jude 2001).

Physiology and Adaptability

An established population of Northern Madtom in the turbid Thames River suggests that it is tolerant of some level of turbidity. Turbidity in the upper Thames River, where the Northern Madtom has been collected, ranges between 9.4 and 13.2 Jackson Turbidity Units (JBU), which is considered moderately turbid. Turbidity in the lower Thames (69.5 JBU) is considered as high (TRBSRT 1998). Northern Madtom have been observed spawning in artificial nests, with Taylor (1969) reporting them using cans, milk bottles and boxes. MacInnis (1998) found Northern Madtom nesting under artificial goby nests. Two of the other three *Noturus* species that occur within the Canadian range of the Northern Madtom have used similar items elsewhere (broken bottles and inverted toolboxes for the Stonecat (Stewart and Watkinson 2004) and beer

cans for Brindled Madtom (Burr and Mayden 1982). While captive rearing and translocations have not been attempted for the Northern Madtom, Shute *et al.* (2005) succeeded with the closely related *Noturus flavipinnis* (Yellowfin Madtom), and *N. baileyi* (Smoky Madtom). Several other researchers have successfully hatched and reared eight other species (Mayden *et al.* 1980; Burr and Dimmick 1981; Mayden and Burr 1981; Burr and Mayden 1982a; Burr and Mayden 1982b; Mayden and Walsh 1984; Stoeckel and Neves 2000). None of these were translocated.

Dispersal and Migration

There is no published information on the movements or migration of the Northern Madtom. However, from June to August 2010, two individuals that were tagged at Belle Isle near Peche Island on the American side of the Detroit River were re-captured two months later approximately 1.0 km to the east in Canadian waters. This movement involved crossing a deep 8-9 m shipping channel that includes a busy shipping lane (B. Manny, pers. comm. 2010). One other Northern Madtom was re-captured 0.5 km away, between sampling sites in the American portion of the upper Detroit River (B. Manny, pers. comm. 2010).

Interspecific Interactions

The Northern Madtom is generally found with other benthic species that require similar habitats. In the St. Clair River, they have been collected with Logperch (*Percina caprodes*), Mottled Sculpin (*Cottus bairdii*), and the introduced Round Goby (*Neogobius melanostomus*) (see Threats Section) (French and Jude 2001). In the Detroit River, the most common species captured with Northern Madtom was Round Goby. Rock Bass (*Ambloplites rupestris*), Smallmouth Bass (*Micropterus dolomieu*), Logperch, Yellow Perch (*Perca flavescens*), and Brindled Madtom were also captured in low numbers (B. Manny, pers. comm. 2010). In the Thames River, other benthic insectivores of similar size captured with Northern Madtom were Stonecat, Johnny Darter (*Etheostoma nigrum*) and the provincially endangered Eastern Sand Darter (Edwards and Mandrak 2006; M. Finch, unpubl. data; A. Dextrase, pers.comm. 2010).

Both Tzilkowksi and Stauffer (2004) in Pennsylvania and Scheibly *et al.* (2008) in Kentucky found that Northern Madtom share spawning habitat with the Stonecat. Scheibly *et al.* (2008) also encountered Brindled Madtom in a spawning raceway. Stonecats are also associated with Northern Madtom at the type locality in the Huron River, Michigan (MNFI 2010).

POPULATION SIZES, TRENDS AND ABUNDANCE

The Northern Madtom has been collected using a variety of techniques. Occasionally it has been collected while sampling for other species. There have not been any specific studies on population sizes in Canada. Therefore, it is difficult to assess population sizes and trends. The low capture rates at most sites also make it

difficult to ascertain population sizes, trends and abundance. It is unclear whether the low capture rates of Northern Madtom in Canada are a result of degraded habitat from anthropogenic sources, habitat limitations at the northern edge of its range, difficulty in sampling the species effectively, or the species' apparent scarcity wherever it occurs (Thomas and Burr 2004).

As population size, trend and abundance estimates are not possible for the species, the following is a summary of total numbers captured or observed in Canadian waters.

Approximately 235 Northern Madtom have been captured or observed at 66 sites. Approximately 165 Northern Madtom have been either captured or observed from 25 sites in the Detroit River. This includes approximately 50 individuals captured while trawling or being observed by A. MacInnis in 1996 in the area around Peche Island.

In Lake St. Clair, 27 individuals have been captured or observed at 5 sites. This includes 21 Madtom observed on nests in 1996 near the source of the Detroit River, three juveniles near the mouth of Belle River, and one individual found dead on the south shore of Lake St. Clair near the outlet of Pike Creek (ROM, unpubl. data).

In the St. Clair River, seven individuals have been collected at six sites. All but one were collected in October 2010 (J. Barnucz, pers. comm. 2010).

In the Sydenham River, a single specimen was taken near Florence in 1975 (NMC 75-1623). It was originally identified as a Brindled Madtom (*Noturus miurus*), but was re-examined by Erling Holm in 1999 and determined to be a Northern Madtom. A second specimen, again originally identified as a Brindled Madtom, was collected near Alvinston, Ontario in 1929. It was recently re-examined by Erling Holm, and, although very faded, appears to be a Northern Madtom. Despite repeated sampling near Florence (1989, 1991, 1997, 1999, 2001, 2003), no other Northern Madtom have been captured. In 2010, the Lower East Sydenham River (Dawn Mills to Tupperville) was sampled using benthic trawls and night seining in the later period. Again, no Northern Madtom were captured (J. Barnucz, pers. comm. 2010). With no individuals collected since 1975, it is likely that the species has been extirpated from the Sydenham River (Edwards *et al.* 2012).

In the Thames River, 34 Northern Madtom have been collected from 28 sites between Littlejohn Road and Tate Corners. The majority of the sites are located in, or near, the Big Bend Conservation Area.

Spawning has been observed in Lake St. Clair near the source of the Detroit River (MacInnis 1998). Adult Northern Madtom were also found in cavities of half blocks inside egg mats designed for Lake Sturgeon in the Detroit River near Belle Isle (Manny 2006). The collection of several individuals in the juvenile size range (i.e. <60mm SL) in all waterbodies also suggest that reproduction is occurring, and that these populations may be stable (COSEWIC 2002). Reproduction in and of itself, however, does not

necessarily indicate a stable population. Due to low numbers of Northern Madtom captured in Canadian waters, however, population structure and variability remains difficult to ascertain.

Sampling Effort and Methods

Catch rates for the Northern Madtom in Canada have been too low to implement methods for estimating populations. On the American side of the Detroit River, 197 madtoms were tagged with visual implant tags and released in hopes of re-capturing enough individuals to obtain a population estimate. With only 6 re-captures, a population estimate could not be determined with a reasonable level of uncertainty (B. Manny, pers. comm. 2010).

See "Search Effort" section for sampling effort and methods undertaken in Canadian and shared waters.

Fluctuations and Trends

The paucity of demographic data and population abundance in Canada limits the ability to properly assess population fluctuations and trends (Edwards *et al.* 2012). It does appear, however, that habitat improvements in the Detroit River have resulted in increased catches of Northern Madtom. Also, the capture of 15 individuals at four sites in the Fleming Channel in 2011 represents the highest capture rate DFO has achieved since targeted sampling began.

Rescue Effect

Several hundred Northern Madtom have been collected on the American sides of the Detroit (B. Manny, pers. comm. 2010) and St. Clair rivers (French and Jude 2001). As these waterbodies are shared between Canada and the United States, it is possible for Northern Madtom to disperse into Canadian waters. Dispersal of Northern Madtom from the American side to the Canadian side of the Detroit River has been documented (B. Manny, pers. comm. 2010). Recent improvements to water quality and habitat in the Detroit River appear to have benefited Northern Madtom there.

THREATS AND LIMITING FACTORS

Threats

NatureServe (2011) states that declines in Northern Madtom populations are due to channelization, increased turbidity, siltation, and chemical runoff from agriculture and urbanization, pollution, and declining water quality. However, no studies documenting these effects on the species have been published.

Several threats to the Northern Madtom in Canada have been identified, and a summary of threat classifications from Edwards *et al.* (2012) is provided in Table 3. These include habitat loss and degradation, siltation and turbidity, nutrient loadings, toxic compounds, exotic species, and climate change. Many of these are directly tied to the agricultural and urban land uses that dominate the local landscape. While Edwards *et al.* (2012) stated that the above are considered to be "potential threats as they have not been demonstrated empirically", a detailed discussion of these threats is warranted.

Table 3. Threat classification table for Northern Madtom (from Edwards *et al.* 2012).

Specific Threat	Extent (widespread/ localized)	Frequency (seasonal/ continuous)	Causal Certainty (high, medium, low)	Severity (high, medium, low)	Overall Level of Concern (high, medium, low)
Thames River					
Siltation	Widespread	Continuous	Medium	High	High
Turbidity	Widespread	Continuous	Low	High	High
Nutrient Loadings	Widespread	Continuous	Medium	High/Medium	High
Exotic Species	Localized	Unknown	Medium	Low (increasing)	High
Toxic Compounds (pesticides/herbicides)	Localized	Seasonal	Medium	Medium	Medium
Habitat Loss/Degradation	N/A	N/A	N/A	N/A	N/A
Detroit River/Lake St. Clair					
Siltation	Localized	Continuous	Medium	Low/Medium	Medium
Turbidity	Widespread	Continuous	Low	Low	Low
Nutrient Loadings	Widespread	Continuous	Medium	Medium/High	Medium?
Exotic Species	Widespread	Continuous	Medium	High	High
Toxic Compounds	Detroit River – Widespread; Lake St. Clair – Localized	Continuous	Medium	High	High
Habitat Loss/Degradation	Localized	Continuous	Medium	High	High
St. Clair River					
Siltation	Localized	Continuous	Medium	Low/Medium	Medium
Turbidity	Widespread	Continuous	Low	Low	Low
Nutrient Loadings	Widespread	Continuous	Medium	Medium/High	Medium?
Exotic Species	Widespread	Continuous	Medium	High	High
Toxic Compounds	Widespread	Continuous	Medium	High	High
Habitat Loss/Degradation	Localized	Continuous	Medium	High	High
All Populations					
Climate Change	Widespread	Continuous	High	Low	Low

Destruction of habitat is believed to be the primary threat to endangered fish species (Wilcove *et al.* 1998). Dextrase and Mandrak (2006) considered habitat loss and degradation to be the two primary threats to aquatic species at risk in Canada. Chan and Parsons (2000) state that the greatest risk to madtom conservation is habitat destruction. Benthic fishes, including several *Noturus* species, are experiencing disproportionate rates of extirpation and imperilment because stream substrates are often the first impacted habitat type (Angermeier 1995; Warren *et al.* 1997 in Midway *et al.* 2010). The restricted distribution of many madtom species further increases vulnerability to habitat destruction (Piller *et al.* 2004). Simon (2006) stated that habitat loss has caused the local extirpation of the Northern Madtom in the Wabash River.

Potential physical habitat loss specific to Northern Madtom in Canada includes dredging the shipping corridor from the St. Clair River to Lake Erie, as well as lake and river shoreline modifications (e.g., shoreline stabilization projects, docks, marinas) along the Detroit River and Lake St. Clair (Manny 2003; Dextrase and Mandrak 2006). Larson (1981) stated that dredging of the shipping channels in the Detroit River has altered large areas of substrate from a complex limestone environment to homogeneous bedrock and clay habitats. Loss of habitat heterogeneity may increase predation risk, decrease availability of prey, and, therefore, foraging success.

Siltation, turbidity, and channelization are also potential threats to the Northern Madtom in Canada. In the United States, NatureServe (2011) identifies channelization as the most serious threat facing the species, followed by increased siltation and turbidity. Bailey and Yates (2003) stated that direct soil deposits through agricultural tile drainage systems and overland runoff has the largest influence on siltation rates. Additionally, the level of sediment input, as well as the rate of streambank and shoreline erosion, increases when channelization and loss of riparian zones occurs (Bailey and Yates 2003). This loss can occur through ploughing or livestock grazing to the edge of a watercourse (Bailey and Yates 2003). While increases in turbidity might not affect feeding activity patterns, as the Northern Madtom is nocturnally active and so does not require light to forage, decreased primary productivity due to reduction in light penetration might reduce available food sources. Deposition of sediment can cover coarse substrates, and might affect the species' ability to nest in cavities (Dextrase *et al.* 2003).

Habitat quality can be adversely affected by increased nutrient loading. Phosphorus and nitrogen levels can increase due to agricultural fertilization and manure use practices. Effluents from sewage treatment plants and faulty septic systems can also increase nutrient loadings (Edwards *et al.* 2012). Adverse effects to the aquatic ecosystem include increased frequency of algal blooms, increased growth of macrophytes, increased turbidity, and disruption of food webs (Bailey and Yates 2003).

Given the presence of Northern Madtom in the Detroit and St. Clair rivers, both of which have been designated Areas of Concern (AOC), it would appear that the species is somewhat tolerant to toxic compounds. Those compounds present in the Detroit and St. Clair rivers include PCBs, PAHs, metals, oils and greases (U.S. Environmental Protection Agency 2009). In the Thames River, pollutants may include chloride (e.g., from road salt, wastewater treatment and water softeners) and metals, as well as pesticides from both agricultural and urban areas (TRERT 2004). While still below the Environment Canada guidelines for sensitive aquatic species, chloride levels in the Thames River have shown a continual increase over the past 30 years (TRERT 2004). In the midwestern United States, Wildhaber *et al.* (2000) suggested that the closely related Neosho Madtom (*Noturus placidus*) is limited by the presence of heavy metals such as cadmium, lead and zinc.

The Great Lakes have a long history of invasion by exotic species and introductions of non-native aquatic organisms. Of these, the Round Goby is thought to present the greatest threat to the Northern Madtom. Since its first detection in the St. Clair River in 1990 and successful reproduction within one year (Jude *et al.* 1992), Round Goby has been implicated in the decline of two other benthic species, Mottled Sculpin and Logperch, in the St. Clair River (French and Jude 2001). While the Round Goby is a mussel specialist, Carman *et al.* (2006) showed that diet is similar to native benthic fishes when mussels are absent from a waterbody. French and Jude (2001) found significant diet overlap between Round Goby and Northern Madtom at 3 m depth in the St. Clair River. However, nocturnal foraging by Northern Madtom might reduce temporal competition for food. As both species are cavity nesters, competition for nest sites might exist. However, MacInnis and Corkum (2000) found that spawning seasons of the two species barely overlapped, with Round Goby spawning earlier in the year. French and Jude (2001) found that large Northern Madtom preyed on young-of-year Round Goby, but that the reverse was not observed. The presence of dorsal and pectoral spines which possess venom (Scott and Crossman 1973) may protect Northern Madtom from predation by Round Goby. It is possible, however, that Round Goby could prey on Northern Madtom larvae or spawn.

During recent sampling targeted at Northern Madtom in the Detroit River, Round Goby was captured in 4 of the 5 trawls that produced Northern Madtom, and in those trawls, the ratio of goby to madtom ranged from 3:1 to 15:1 (N. Mandrak, pers. comm., 2011). While the Northern Madtom population in the Thames River has not yet had to co-exist with Round Goby, considerable upstream movement of gobies to new areas of the river was documented in 2006 (Poos *et al.* 2010). Roundy Goby has also been confirmed in the Sydenham River, just downstream of the recorded occurrence of Northern Madtom at the town of Florence (Poos *et al.* 2010).

Potential negative impacts of the exotic Zebra Mussel (*Dreissena polymorpha*) and Quagga Mussel (*D. bugensis*) on Northern Madtom include reduction in the colonization of potential nesting cavities, as well as alteration of food web dynamics and surrounding water quality (Edwards *et al.* 2012). Increased populations of these mussels could, however, reduce diet overlap between Round Goby and Northern Madtom.

Climate change models predict that several aquatic species like Northern Madtom potentially will be affected. In the Great Lakes basin, it is expected that air and water temperatures will increase; duration of ice cover will shorten; frequency of extreme weather events will increase, diseases will spread, and predator-prey dynamics will shift (Lemmen and Warren 2004). Like many species at risk in southern Ontario, Northern Madtom is at the northern edge of its global range. While coldwater species may be extirpated from much of their present range if water temperatures increase, warmwater species like Northern Madtom may expand northwards (Chu *et al.* 2005). However, this benefit might be offset by several factors, including decreased lake and summer stream water levels, changes in evaporation patterns and vegetation communities, and increased intensity and frequency of storms (EERT 2008).

Limiting Factors

Edwards *et al.* (2012) stated that several factors may limit Northern Madtom populations in Canadian waters. These include spawning habitat requirements, minimal temperature for spawning, and fecundity and maximum age. Given that the Northern Madtom is a cavity nester that appears to have responded positively to restoration of habitat heterogeneity in the Detroit River (B. Manny, pers. comm. 2010), it is possible that benthic habitat homogeneity in areas that are actively dredged for shipping, as well as in other waterbodies throughout its Canadian range, is limiting spawning success.

Spawning occurs when water temperature reaches a minimum of 23°C (Taylor 1969; MacInnis 1998; Scheibly *et al.* 2008). This is the same spawning temperature recorded for the Stonecat in Manitoba (Stewart and Watkinson 2004). Since it was first documented in the Red River drainage in 1969 (Stewart and Lindsey 1970), the Stonecat has dispersed as far north as the Assiniboine River at Shellmouth, MB (50°56'N), where the Shellmouth Dam has blocked further dispersion (McCulloch and Stewart 1998). This latitude is approximately 8° north of the northernmost Northern Madtom record in the St. Clair River near Sarnia. Therefore, minimum spawning temperature might not be an issue. However, information on the ability of Northern Madtom to disperse is very limited, and any significant northward expansion would not occur via a riverine pathway, but rather through the coldwater lentic environment of Lake Huron. Reproductive success in the northern peripheral populations, such as in the St. Clair River, might improve as water temperatures increase due to climate change.

Edwards *et al.* (2012) suggested that the availability of silt-free cavities in which to create nests might limit spawning potential. Competition for suitable spawning sites might occur with congeners, Brindled Madtom and Stonecat, and the Round Goby. Northern Madtom were observed in an excavated nest site below an artificially constructed Round Goby nest (MacInnis 1998).

With a maximum age of 3 years (Scheibly *et al.* 2008), and maturity reached at 2 years, the Northern Madtom likely spawns, at most, only twice. Reliance on one or two cohorts for recruitment into the population can threaten population stability (Simonson and Neves 1992).

Finally, Northern Madtom is a low fecund species and could be affected negatively by the altered habitat and fish communities in which they occur and interact (Edwards *et al.* (2012). This effect might be at least partially offset, however, due to the parental care undertaken by the species. This strategy ensures increased survival of eggs and young.

PROTECTION, STATUS, AND RANKS

Legal Protection and Status

Northern Madtom was designated by the Committee on the Status of Endangered Wildlife in Canada (COSEWIC) as Endangered in 2002 and 2012. The species has the general protection given by habitat provisions within the *Fisheries Act*. It is currently on Schedule 1 of the Canadian *Species at Risk Act*, making it an offence to kill, harm, capture, take, possess, collect, buy, sell or trade Northern Madtom, or damage or destroy its residence. The *Species at Risk Act* prohibits the destruction of habitat identified as critical in an approved recovery strategy or action plan (SARA, S.C.2002, c.29, s. 57 58), but the competent minister must make an order before the prohibitions apply. A recovery strategy has been proposed for the Northern Madtom that includes the identification of critical habitat within the Detroit River and Lower Thames River. There is currently no action plan for this species, but one or more action plans will be produced by 2013 (Edwards *et al.* 2012).

Under Ontario's *Endangered Species Act*, 2007, the Northern Madtom is listed as "Endangered" and is protected from any actions that may cause harm to the species. However, its habitat will not be protected until 2013 (5 years after the Act came into force in 2008) unless a specific habitat regulation is developed under the Act by the provincial government at an earlier date (Edwards *et al.* 2012).

The Northern Madtom is given partial protection under Ontario's *Planning Act,* which prohibits development and site alteration in the habitat of Endangered or Threatened species, and under Ontario's *Lakes and Rivers Improvement Act,* which prohibits the impoundment or diversion of a watercourse if siltation will result.

While not listed federally in the United States, the Northern Madtom is currently designated as Endangered in Michigan, Ohio, Illinois and Pennsylvania. Protection is afforded under each of these states' endangered species acts. Statutes are available at Animal Legal and Historical Center website (http://www.animallaw.info/statutes/topicstatutes/sttoes.htm).

Non-Legal Status and Ranks

The following ranks were obtained from NatureServe (2011):

Global Rank: G3 (vulnerable) – last reviewed 2008

National Ranks: US: N3 (vulnerable); Canada: N1/N2 (critically imperiled/imperiled)

Sub-national Ranks: AR (SNR), IL (S1), IN (S1), KY (S2S3), MI (S1), OH (S1), PA (S2), WV (S1), ON(S1)

S1 – critically imperiled, S2 – imperiled, S3 – vulnerable, SNR – Not ranked/under review

Both the Canada General Status and Ontario General Status are "At Risk".

Habitat Protection and Ownership

In Canada, the Northern Madtom occurs in publicly owned waters, and all fish habitat within these waters is protected by the federal *Fisheries Act*.

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COLLECTIONS EXAMINED

ROM 6675 was re-examined by Erling Holm.